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BENTHOBATIS YANGI, A NEW SPECIES OF BLIND ELECTRIC RAY FROM TAIWAN (CHONDRICHTHYES: TORPEDINIFORMES: NARCINIDAE)

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ABSTRACT

A new species of electric ray of the genus *Benthobatis* Alcock, 1898 is described on the basis of five specimens from the continental slope off Tungkang, southwestern Taiwan. *Benthobatis yangi*, n. sp., is distinguished from all other species of the genus by a unique combination of characters, including a dark brown to purplish–black dorsal and ventral coloration with irregular creamy blotches ventrally, a narrow nasoral region, a small mouth with slender jaws and shallow circumoral groove, a second dorsal fin with a more broadly rounded apex and more convex posterior margin compared to the first dorsal fin, an interdorsal distance greater than the distance between second dorsal and caudal fins, a narrow and not posteriorly arched suprascapula, size at sexual maturity, and a relatively high number of caudal vertebral centra, and consequently, total vertebral centra. *Benthobatis yangi* is known from adults and juveniles of both sexes. It is only the fourth valid species of *Benthobatis*, and only the second species from the vast Indo-Pacific region. *Benthobatis* is a continental slope, blind electric ray genus that remains poorly understood.

The deep-water, blind electric ray genus *Benthobatis* Alcock, 1898 was recently reviewed by Carvalho (1999b), who recognized four distinct species of which two were undescribed. One of these, referred to as "*Benthobatis* sp. 2," was first recorded and illustrated (as *B. moresbyi*) by Chen and Chung (1971) on the basis of 15 specimens from off Tungkang, southwestern Taiwan. The condition and whereabouts of these specimens is presently unknown, but at least one (THUP 02220, possibly a 316 mm total length, TL, female), illustrated in Chen and Chung (1971), may remain in the ichthyological collection of the Department of Biology, Tunghai University (Taiwan). In addition to the four specimens reported in Carvalho (1999b), a juvenile specimen of this new form was obtained by the third author in the Tungkang fish market in 1988. These five specimens, all from the continental slope of southwestern Taiwan in the South China Sea, form the basis of the present paper, in which they are described as a new species.

The taxonomic history of *Benthobatis* in the Indo-Pacific region is somewhat sporadic. *Benthobatis* was established by Alcock (1898) for a new species of deep-water electric ray from the Indian Ocean, *B. moresbyi*, with a uniform dark coloration both dorsally and ventrally, two dorsal fins and greatly reduced eyes. Three syntypes of *B. moresbyi*, including two males of about 350 mm total length and a smaller individual of unstated size and sex, were originally reported by Alcock (1898) from the Travancore coast of southern India at 787 m in depth. Alcock (1899) gave a verbatim repetition of his original (1898) description, but also attributed to his specimens catalog numbers (232/1–234/1) of the Indian Museum, Calcutta (now Zoological Survey of India, ZSI), without mentioning which of his original specimens was assigned to these numbers. Alcock and McGilchrist (1899) illustrated an adult male *B. moresbyi* in dorsal view (probably one of the two larger syntypes), but without a catalog number, size, or indication of its type status. Lloyd (1907) recorded a small specimen of *B. moresbyi* from the Arabian Sea, off southern Yemen (1071 m), which he later (Lloyd, 1909) assigned to "Indian Museum" (ZSI) no.

1315/1 (currently deposited in London, NHM). Brauer (1908) subsequently reported one additional specimen of *B. moresbyi* from off Somalia (823 m), deposited in Berlin (ZMB). Annandale (1909) illustrated the mouth and teeth of *B. moresbyi* and compared it to his new electric ray *Bengalichthys impennis* (= *Narke dipterygia*). Prior to the generic revision of Carvalho (1999b), the only information on *B. moresbyi* to appear since Annandale's account is a depiction of its teeth in Cappetta (1988), and only five specimens of this species have been reported to date. Carvalho (1999b) summarized all literature related to *B. moresbyi*, figured all specimens except for those that remained in the ZSI, designated a lectotype for this species (deposited in the NHM, London), and provided an identification key to species of *Benthobatis*.

Benthobatis is probably more widespread in the Indo-Pacific region than presently documented, given that it has been recorded from both sides of the Arabian Sea (including the Gulf of Aden) and from the South China Sea. More intensive collecting efforts on the continental slope will likely reveal additional new species. The new species described here has been compared to all congeners, including *Benthobatis marcida* Bean and Weed, 1909 from the tropical western Atlantic and a recently described species from southern Brazil, *B. kreffti* (Rincon et al., 2001).

Terminology and Methods

Institutional abbreviations follow Leviton et al. (1985), except for The Natural History Museum, London (NHM), and LJVC (collection of Leonard J. V. Compagno, housed at the South African Museum, Cape Town). Terminology for morphology and morphometrics is based on Bigelow and Schroeder (1953) for batoids, Compagno and Roberts (1982, 1984) for stingrays, Compagno (1984) for sharks, and Carvalho (1999a, 1999b) for electric rays. Compared to other elasmobranchs, electric rays generally do not retain with precision their original proportions after preservation, a condition that is compounded in species of *Benthobatis*. Their relatively soft bodies, comparatively small size, and the fact that they are trawled from deep-waters account for their poor state of preservation. Specimen NTUM 01712 is the best-preserved (and largest) specimen we have examined, and the proportions presented for it are more reliable than for the other specimens of our new species. Measurements are presented in Table 1, and are listed and defined in the Appendix. Table 2 is a summary of selected morphometric proportions.

Terminology and abbreviations for vertebral counts are based on that for sharks in Compagno (1988) and for stingrays in Compagno and Roberts (1982, 1984). Vertebral counts are presented in Table 3 and are as follows: SYNS, synarcual segments (synarcual segments anterior to synarcual centra determined by count of neural canals through lateral walls of synarcual); SYNC, synarcual centra (centra in posterior end of synarcual); SYN, total synarcual vertebrae (SYNC + SYNS); MP, monospondylous precaudal centra (between posterior end of synarcual and monospondylous-diplospondylous transition); DP, diplospondylous precaudal centra (between MP-DP transition and upper origin of caudal fin); DC, diplospondylous caudal centra (from upper origin of caudal fin to caudal fin tip); TF, total free centra (from posterior end of synarcual to end of caudal centra); TC, total centra (total free centra plus synarcual centra); TS, total segments (all centra plus anterior synarcual segments); %SYN, total synarcual centra as percentage of TF; %MP, monospondylous precaudal centra as percentage of TF; %DP, diplospondylous precaudal centra as percentage of TF; %DC, diplospondylous caudal centra as percentage of TF.

Table 1. Measurements, as percentages of total length (% of TL), for three species of *Benthobatis* (*B. krefftî* not included; TL in mm). Measurements for non-type specimens of *B. marcida* (column on far right) are based on USNM 186428 (169 mm TL) and two uncatalogued specimens from the collection of LJVC (162 and 187 mm TL). One paratype (SIO 70-274, 161 mm TL preadult male, 56 mm DW and 65 mm DL) is excluded from table because of poor preservation. See Appendix for abbreviations. Dashes represent measurements not available in the specimen.

	B. yangi SIO 70–274 holotype	*B. yangi* SIO 70–274 paratype	*B. yangi* NHM 1990.7.18.1 paratype	*B. yangi* NTUM 01712 paratype	*B. moresbyi* NHM 1898.7.13.22 lectotype	*B. marcida* USNM 62916 holotype	*B. marcida* USNM + LJVC non-types
TL	215	191	171	257	353	490	162–187
PRC	85.1	78.5	73.7	82.1	78.5	82.0	77.2–81.7
DW	29.8	30.9	29.8	35.0	39.7	38.0	33.3–35.8
DL	38.6	38.7	41.5	40.8	49.6	43.9	40.1–42.2
DT	5.7	7.2	5.8	6.2	5.9	6.1	8.0–10.1
PRN	11.1	11.4	11.7	10.6	16.4	12.4	7.7–11.2
POR	15.3	15.0	15.2	14.9	21.2	16.1	11.2–14.8
POB	14.5	11.9	15.2	12.8	19.3	16.5	9.5–14.2
PSP	18.6	16.4	16.4	15.6	20.1	18.8	12.4–16.0
PG1	20.5	21.9	22.2	19.3	20.1	23.7	20.1–21.6
HDL	28.4	28.3	29.2	27.2	32.9	31.2	28.4–31.0
PGW	26.8	22.6	25.1	26.6	30.0	–	21.9–33.1
PP2	36.9	33.7	42.7	40.1	47.9	40.8	38.3–41.7
SCL	42.2	42.0	43.9	42.6	49.6	45.9	44.4–46.2
PD1	53.9	51.3	50.3	50.1	52.1	59.2	51.2–54.0
PD2	66.0	63.9	62.6	64.9	68.0	70.2	62.3–66.9
IDS	8.7	12.0	6.4	7.5	2.3	5.1	3.2–7.5
DCS	8.2	9.7	4.7	6.6	0.7	5.5	3.6–10.7
PCA	28.7	26.1	17.5	23.9	12.7	19.2	18.9–23.5
PDO	10.2	13.0	11.7	11.9	9.3	11.4	9.3–15.5
PDI	5.4	4.0	4.7	5.4	3.7	2.0	4.3–5.9
NOW	2.0	2.3	2.6	2.0	2.3	2.0	1.8–4.3
INW	4.7	5.2	1.8	4.4	2.8	8.2	1.9–3.6
IOW	6.0	7.0	5.0	5.9	5.4	9.4	5.9–6.8
SPL	1.5	1.7	0.8	1.1	2.0	2.0	1.6–2.4
SPW	1.5	1.7	0.9	1.3	1.8	–	1.2–1.6
INS	6.6	5.7	5.8	6.2	5.7	8.8	7.1–8.0
MOW	4.2	4.3	4.1	4.2	4.8	4.7	5.3–6.5
GS1	1.2	1.4	1.2	1.1	2.0	1.8	1.2–2.5
GS2	1.2	–	1.2	1.2	2.4	2.0	1.2–2.5
GS3	1.4	–	1.2	1.6	2.8	2.0	1.5–2.5
GS4	1.2	–	1.2	1.6	2.5	1.8	1.8–2.5
GS5	0.7	–	1.3	1.0	2.3	1.6	1.2–1.6
IG1	6.9	7.7	9.1	8.7	9.9	10.8	10.5–12.3
IG5	5.3	5.9	5.8	6.2	8.5	8.6	8.0–8.9
CLL	2.8	2.7	2.9	2.9	4.0	2.4	2.5–3.0
PIW	13.7	12.8	12.6	14.1	12.7	12.7	13.0–16.0
TBH	6.1	3.9	3.5	5.0	4.0	–	4.7–6.2
TBW	6.6	8.0	5.3	7.3	4.5	–	6.4–7.4
CPH	3.3	3.2	2.3	2.9	3.0	2.4	2.4–2.7

Table 1. Continued.

	B. yangi SIO 70–274 holotype	*B. yangi* SIO 70–274 paratype	*B. yangi* NHM 1990.7.18.1 paratype	*B. yangi* NTUM 01712 paratype	*B. moresbyi* NHM 1898.7.13.22 lectotype	*B. marcida* USNM 62916 holotype	*B. marcida* USNM + LJVC non-types
CPW	1.9	2.0	2.3	2.3	1.4	1.6	1.9–2.4
P2L	–	–	17.8	–	–	16.1	12.3–20.1
P2A	7.1	8.7	10.5	8.6	11.3	14.5	5.9–11.2
P2B	12.3	14.6	17.8	15.5	13.9	16.1	13.0–20.1
P2H	11.0	7.4	9.4	8.1	11.3	11.2	5.9–10.7
P2P	12.7	9.1	13.5	13.0	13.6	15.9	11.7–15.4
P2S	23.3	16.5	22.8	20.0	26.9	24.9	22.8–26.0
CLO	4.0	5.2	–	–	4.0	–	–, 4.9
CLI	11.8	13.4	–	–	13.6	–	–, 13.0
CLB	2.0	2.3	–	–	1.4	–	–, 2.5
D1L	–	–	10.5	–	13.6	9.6	4.8–8.3
D1A	7.4	5.1	10.5	9.4	12.5	10.4	5.9–9.9
D1B	5.3	4.5	8.2	8.0	11.3	7.3	4.8–8.3
D1H	7.5	4.5	3.5	6.3	4.8	5.7	3.0–5.6
D1I	–	–	2.5	–	2.5	3.7	–, 1.5
D1P	–	–	1.8	–	3.4	4.7	3.6–4.9
D2L	–	6.2	12.6	9.4	13.0	13.1	5.9–8.9
D2A	8.4	7.5	12.6	10.5	12.5	12.4	7.0–10.5
D2B	6.7	5.1	8.2	7.8	11.6	9.6	4.3–8.9
D2H	7.5	5.2	4.4	6.8	4.5	5.7	3.8–6.2
D2I	–	1.1	4.1	2.1	2.8	2.4	–, 2.5
D2P	–	–	2.9	3.3	3.1	5.3	3.6–4.3
CDM	17.1	18.4	23.4	19.1	20.7	17.3	17.8–20.3
CPM	18.0	18.4	25.1	20.7	26.3	8.0	18.2–20.7
CHI	4.7	4.3	4.1	6.0	5.9	8.6	5.9–8.6
EOL	23.2	23.0	33.0	21.4	17.2	–	–
EOW	7.0	8.1	12.0	7.4	8.9	–	–

Systematics

Family Narcinidae Gill, 1862

Genus *Benthobatis* Alcock, 1898

Blind electric rays

Benthobatis Alcock, 1898: 144 (original description, not illustrated). Type species: *Benthobatis moresbyi* Alcock, 1898, by original designation and monotypy. Gender feminine. There are no generic synonyms.

Table 2. Measurement ratios for three species of *Benthobatis* (*B. kreffti* not included). See Appendix for abbreviations.

	B. yangi NTUM 01712 paratype	*B. yangi* NHM 1990.7.18.1 paratype	*B. moresbyi* NHM 1898.7.13.22 lectotype	*B. marcida* USNM 62916 holotype	*B. marcida* USNM 186428 non-type	*B. marcida* LJVC uncat. non-type	*B. marcida* LJVC uncat. non-type
TL (mm)	257	171	353	490	169	162	187
DW/DL	0.85	0.72	0.80	0.87	0.83	0.83	0.85
POR/MOW	3.5	3.71	4.41	3.43	1.73	2.40	2.40
HDL/GS3	17.0	25.0	11.60	15.30	18.46	12.50	14.50
HDL/MOW	6.5	7.14	6.82	6.65	4.36	5.00	5.80
CPH/CPW	1.3	1.00	2.10	1.50	1.00	1.33	1.25
DCS/CPH	2.3	2.00	0.24	2.25	1.50	2.50	4.00
IDS/D1B	0.93	0.79	0.20	0.69	0.39	1.11	1.56
CDM/D1B	2.4	2.86	1.83	2.36	2.14	3.56	4.22
D1B/D1H	1.3	2.33	2.35	1.29	2.80	1.00	0.90
D2H/D1H	1.1	1.25	0.94	1.00	1.28	1.11	1.00
D2B/D1B	1.0	1.00	1.03	1.31	1.07	1.00	0.89
DCS/D2B	0.8	0.57	0.06	0.57	0.40	1.11	2.50
D2B/D2H	1.1	1.87	2.56	1.68	2.34	0.90	0.80
CDM/CHI	3.2	5.71	3.48	2.02	3.00	2.29	2.92

Definition.— Generic monophyly is supported by the following derived characters: (1) eyes vestigial and presumably non-functional or barely so (an independent state of blindness is derived for the narkid electric ray genus *Typhlonarke* Waite, 1909); (2) rostrum very broad and anteriorly divergent close to snout margin (much broader anteriorly than in any other torpediniform genus; Carvalho, 1999a); (3) spatulate tips of prepelvic processes mushroom-shaped, with posteriorly directed extremities. A further character (dorsal projection of the nasal capsules not as pronounced as in other narcinids), presently of uncertain polarity, may also be a derived feature of the genus (nasal capsule dorsal projections are a narcinid synapomorphy; Carvalho, 1999a). Carvalho (1999b) provides additional external morphological characters diagnostic for *Benthobatis*.

Species Composition.—*Benthobatis moresbyi* Alcock, 1898 (type-species), *B. marcida* Bean and Weed, 1909 (including *B. cervina* Bean and Weed, 1909), *B. krefftі* Rincon, Stehmann and Vooren, 2001, and *B. yangi*, n. sp. (see Carvalho, 1999b, for generic summary).

Distribution.—As currently known, *Benthobatis* has a remarkably disjunct and sporadic distribution, occurring on the continental slopes of southeastern North America, southern Brazil, northeastern Africa, the Indian subcontinent, and off southwestern Taiwan. In the western North Atlantic, *B. marcida* is known from off South Carolina at 646–745 m, from off Florida at 683–922 m, and from off the north coast of Cuba at 275–642 m (Bigelow and Schroeder, 1953; Carvalho, 1999b). The southwestern Atlantic form *B. krefftі* is known from abundant material from the continental slope of southern Brazil at depths ranging from 470–527 m (Rincon et al., 2001). In the northwestern Indian Ocean (Arabian Sea), *B. moresbyi* is known from off Somalia at 823 m, from off south Yemen at 1071 m, and from the Travancore (southwest) coast of India at 787–1071 m (Annandale, 1909; Carvalho, 1999b). *Benthobatis yangi*, n. sp., is recorded so far only from off south-

western Taiwan, and apparently occurs on the upper continental slope or outer shelf at 300 m or less.

Material Examined.—Extensive material of *B. marcida*, including type-material of *B. cervina*, was examined for this study and is listed in Carvalho (1999b). Most specimens of *B. moresbyi* (the only exceptions are two paralectotypes possibly extant in the ZSI, Calcutta) and two paratypes of *B. kreffti* were also examined (ISH 1989-1968; Carvalho, 1999b). To these specimens we add the following lots of *Benthobatis marcida*: USNM 186428, 16 specimens from the north coast of Cuba, including 8 females, 94–211 mm TL, three adult males, 160–171 mm TL, one adolescent male, 113 mm TL, and four immature males, 93–120 mm TL (listed in Carvalho, 1999b, but examined in more detail for the present study); LJVC uncat., 182 mm TL adult female and 162 mm TL adult male, RV Silver Bay, off Florida, 29°53′N, 080°10′W, 366 m.

Benthobatis yangi new species

Taiwanese blind electric ray

(Figs. 1–7, Tables 1–3)

Benthobatis moresbyi: Chen and Chung, 1971: 5–6, fig. 3 (description, illustration; 15 specimens, 135–316 mm TL); Shen, 1984a: 5, pl. 5 (brief description, photograph; southwestern Taiwan); Shen, 1984b: 40 (name only); Yu, 1988: 9 (listed); Chen and Joung, 1993: 79, 621, pl. 11 (brief description, photograph; Taiwan); Li et al., 2001: 335–336, fig. 175 (brief description, illustration; 4 specimens, 225–258 mm TL).

Benthobatis sp. 2: Carvalho, 1999b: 252–253, figs. 4C, 5 and 10 (diagnosis, distribution, color photograph; Taiwan).

Benthobatis sp.: Carvalho et al., 2000: 1438 (identification, brief description, illustrated; Taiwan); Compagno, 2000: 581 (listed, South China Sea).

Holotype.—SIO 70–274, 215 mm TL adult male, 22°28.0′N, 120°26.0′E, off Tungkang, Taiwan, sta. SDSC 70–143, otter trawl, precise depth unrecorded, obtained on dock by L. Chen, 30. vi. 1970 (Fig. 1).

Paratypes.—(4 specimens): NHM 1990.7.18.1, off Tungkang, Taiwan, 22°26′N, 120°30′E, demersal shrimp trawl haul at 300 m or less, obtained in Tungkang fish market by D. A. Ebert, 22. iv. 1988, 1600 hrs, along with *Eridacnis radcliffei*, *Cephaloscyllium* sp., and *Etmopterus splendidus*; SIO 70–274 (2 specimens), 191 mm TL adult male, 161 mm TL pre-adult male, 22°28.0′N, 120°26.0′E, off Tungkang, Taiwan, sta. SDSC 70–143, otter trawl, obtained on dock by L. Chen, 30. vi. 1970 (Fig. 3); NTUM 01712, off Tungkang, Taiwan, 13. xi. 1972 (Fig. 2).

Diagnosis.—*Benthobatis yangi* is distinguished from all congeners by the following unique combination of characters: coloration on both dorsal and ventral surfaces dark brown to purplish-black, with irregular whitish blotches ventrally; narrow nasoral region, with relatively small mouth, slender jaws and shallow circumoral groove; spiracles relatively small; gill-slits very narrow; second dorsal fin slightly larger than first, with more slanted anterior margin, broadly rounded apex, and convex posterior margin; caudal fin low and relatively elongated; interdorsal distance greater than distance between second dorsal and caudal fin; suprascapula very narrow and not arched posteriorly; sexual maturation for males occurring between 191–215 mm TL; relatively high number of caudal vertebral centra (38–46) and consequently total vertebral centra (116–120).

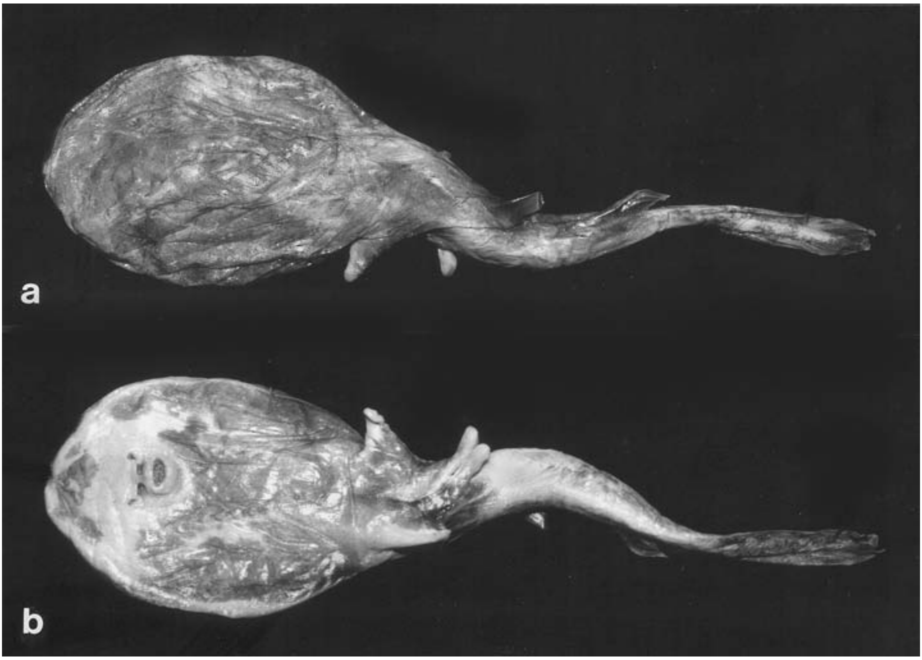

Figure 1. Holotype of *Benthobatis yangi*, n. sp., in dorsal (a) and ventral (b) views (SIO 70–274, 215 mm TL, adult male, off Tungkang, Taiwan, South China Sea).

Description.—Proportions as percentages of total length (% TL) are presented in Table 1, ratios of various measurements are presented in Table 2, and vertebral counts are given in Table 3.

Disc oval and elongate, about 1.5 times as long as broad; edge of disc a continuous curve, with snout, pectoral anterior margins, pectoral apices, and posterior and inner pectoral margins not distinct and merging with sides of tail base. Disc widest just posterior to its mid-length. Electric organs visible through skin of ventral surface, elliptical and about 2.5 times as long as wide. Tail from center of cloaca to caudal tip about 1.2 times as long as snout-cloaca length. Tail rounded in cross section anteriorly at level of posterior pelvic fins, but taller than wide closer to caudal fin. Sides of tail with a low, ridge-like lateral tail fold from about opposite rear third of first dorsal base origin to about one third of caudal length posterior to upper caudal origin.

Prespiracular head length about three times interspiracular width; preoral length about three times as great as outer internarial distance. Eyes undeveloped, orbits entirely covered with integument and not visible externally; positions of eyes indicated by two small, unpigmented spots or pores anterior to spiracles (more obvious in NTUM 01712). Spiracles relatively small, at the bottom of longitudinal, ovate pits; transverse valve anteriorly closing spiracles in holotype and some paratypes; spiracle height about 6.5 times in interspiracular distance; spiracles very deep and with smooth unraised margins. In NTUM 01712, five pseudobranchial lamellae present very deep inside anterior wall of right spiracle, but six in left; pseudobranchial lamellae present in holotype and other paratypes, but very deep within spiracular cavity. A pair of inconspicuous endolymphatic foramina present on nuchal region. Gill openings relatively small, only slightly arched; third gill opening usually the largest; distance between inner ends of first gill-slits about 1.5 times

Figure 2. Paratype of *Benthobatis yangi*, n. sp., in dorsal (a) and ventral (b) views (NTUM 01712, 257 mm TL adult female, off Tungkang, Taiwan, South China Sea).

Table 3. Vertebral counts for species of *Benthobatis*. See Terminology and Methods for abbreviations. For *B. marcida* (LJVC specimens) and *B. krefftti* (ISH specimens; both adult males) only one value is given if it is identical for both specimens included in the table.

	B. yangi SIO 70–274 holotype	*B. yangi* NTUM 01712 paratype	*B. yangi* NHM 1990.7.18.1 paratype	*B. moresbyi* NHM 1898.7.13.22 lectotype	*B. marcida* USNM 186428 non-type	*B. marcida* LJVC uncat. 2 specimens non-types	*B. krefftti* ISH 1989–1968 non-types
TL (mm)	215	257	171	353	169	162, 187	193, 162
SYNS	7	8	8	9	10	9	8
SYNC	5	5	3	4	4	1	3
SYN	12	13	11	13	14	10	11
MP	13	16	19	15	15	16, 17	14, 15
DP	60	53	52	59	48	54	67, 55
DC	42	46	46	38	33	32	34, 31
TF	115	115	117	112	96	102, 103	115, 101
TC	120	120	120	116	100	103, 104	118, 114
TS	126	128	128	125	110	112, 113	126, 122
%SYN	10.4	11.3	9.4	11.6	14.6	9.8, 9.7	9.6, 10.9
%MP	11.3	13.9	16.2	13.4	15.6	15.7, 16.5	12.1, 14.6
%DP	52.2	46.1	44.4	52.7	50.0	52.9, 52.4	58.3, 54.5
%DC	36.5	40.0	39.3	33.9	34.4	31.4, 31.1	29.6, 30.7

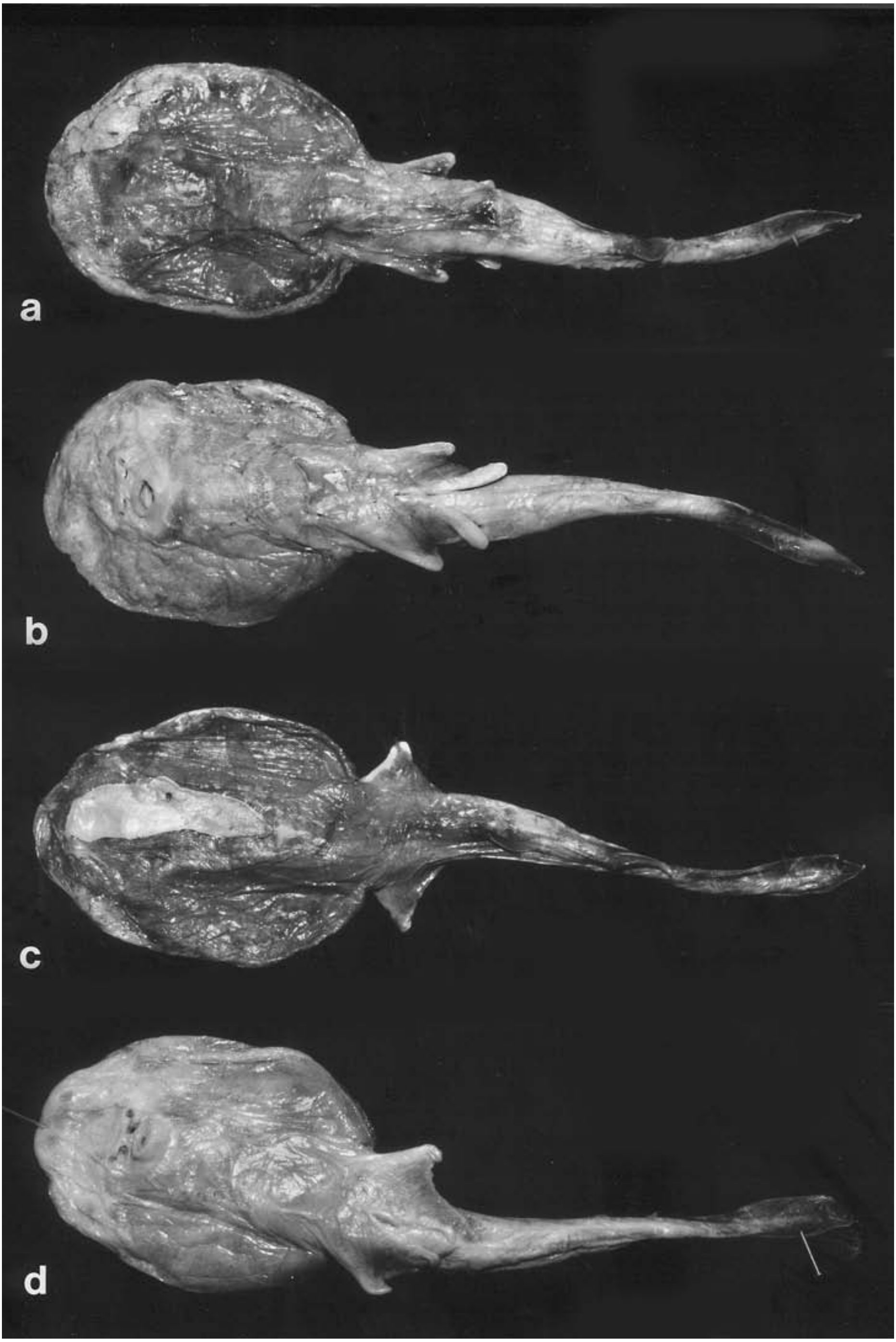

Figure 3. Paratypes of *Benthobatis yangi*, n. sp. (a) dorsal view of SIO 70–274 (191 mm TL, adult male, off Tungkang, Taiwan, South China Sea); (b) ventral view of same; (c) dorsal view of SIO 70–274 (161 mm TL, adult male); d) ventral view of same.

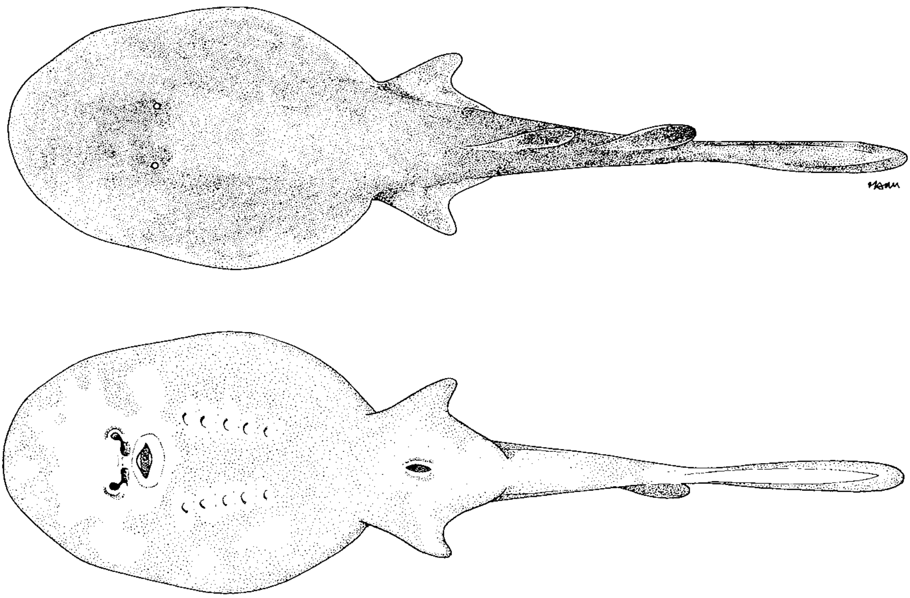

Figure 4. *Benthobatis yangi*, n. sp. (southwestern Taiwan, South China Sea), depicted in dorsal (top) and ventral (bottom) views (modified from Carvalho et al., 2000).

that between fifth gill-slits. Exposed portions of incurrent apertures of nostrils circular and somewhat elevated below level of head. Excurrent apertures open broadly to posterior surface of snout in front of mouth; isthmus between inner ends of excurrent apertures (internarial space) conspicuously exposed, internarial distance about 2.3 in mouth width when jaws are retracted and mouth closed. Nasal curtain very short (Fig. 5), consisting of separate anterior nasal flaps with a low connecting septum; each flap with a strong mesonarial flap above its posterior tip. Outer edge of excurrent apertures expanded as a relatively high fleshy lobe directed inward toward mesonarial flap. A shallow transverse pit or pouch immediately posterior to rear edge of each excurrent aperature in the nasoral groove in front of mouth. Mouth with somewhat thick, smooth lips and surrounded by a moderately shallow circumoral groove; prominent labial folds encase labial cartilages present at corners of mouth; mouth width about 1.5 times in interspiracular distance; mouth and jaw tips forming a short tube when protracted and opened. Tooth bands occupying about 0.8 of mouth width.

Teeth in quincunx arrangement, in 7–1–7/6–1–7, or 15/14 rows in NTUM 01712 and larger SIO paratype, and in 6–1–6/5–1–5, or 13/11 rows in NHM paratype (teeth missing in holotype). Teeth similar in both jaws, continuously varying in size along dental bands, with medial teeth largest; crown bases transversely wide and ovate; posterior teeth smaller and with less expanded crown bases; functional teeth with a single short, slender and sharp cusp, directed rearward into mouth; one to three series of teeth exposed on anteroventral surfaces of jaws when mouth is closed.

Pelvic fins poorly preserved in most specimens; pelvic fins not greatly thickened and fleshy, and somewhat triangular in dorso-ventral perspective; pelvic origins just anterior to pectoral insertions; anterior margins slightly convex, apices narrowly rounded, posterior margins deeply concave with fins fully spread; inner margins of pelvic fins not dis-

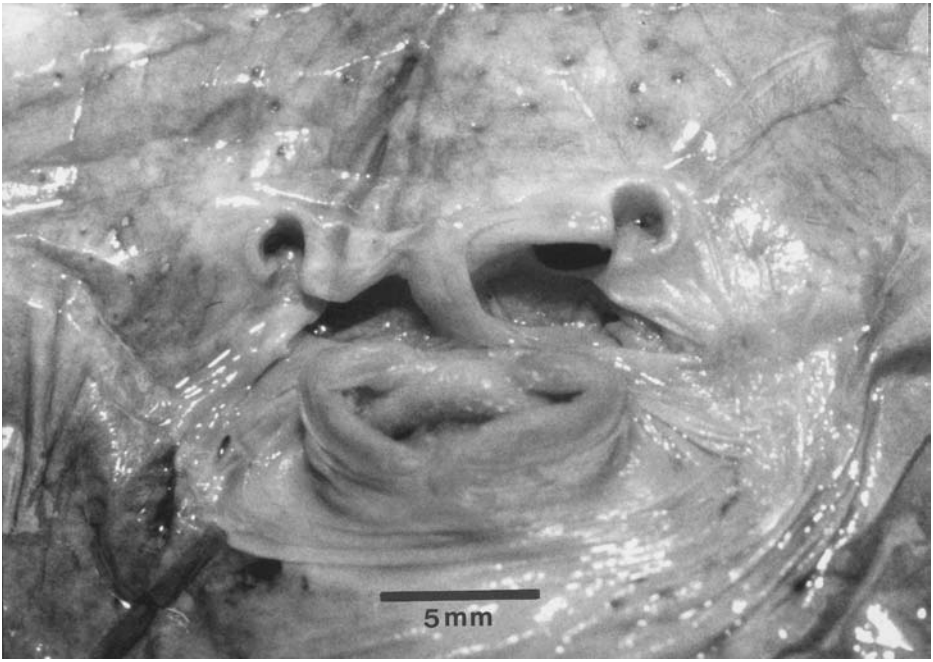

Figure 5. Nasoral region of *Benthobatis yangi*, n. sp. (NTUM 01712, 257 mm TL adult female, off Tungkang, Taiwan, South China Sea); nasal curtain is slightly raised on its left side to expose excurrent aperture.

tinct, with pelvics attached to sides of tail at rear tips; pelvic length about half disc width. Clasper projecting by about two-thirds of its length beyond pelvic posterior margins; clasper broadly oval in cross-section, and with wider, spatulate clasper-tip; clasper groove extends posteriorly somewhat diagonally, ending in a small depression; ventral pseudosiphons longer than dorsal pseudosiphon (Fig. 6); dorsal pseudosiphon wraps around

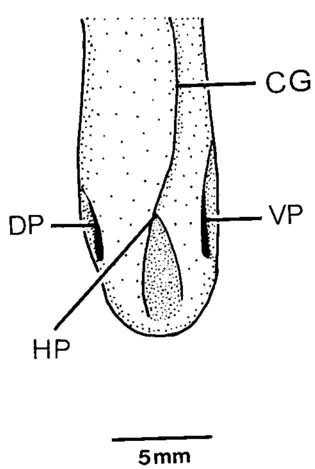

Figure 6. Dorsal view of right clasper of *Benthobatis yangi*, n. sp. Abbreviations: CG, clasper groove; DP, dorsal pseudosiphon; HP, hypopyle; VP, ventral pseudosiphon.

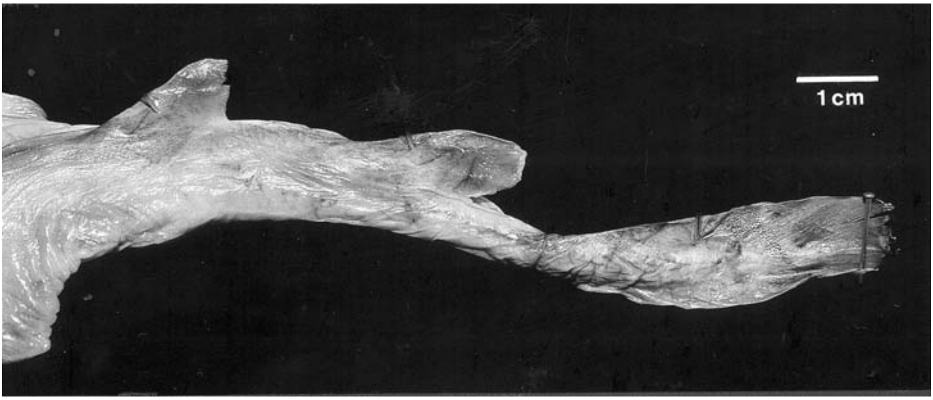

Figure 7. Lateral tail region of *Benthobatis yangi*, n. sp. (NTUM 01712, 257 mm TL adult female, off Tungkang, Taiwan, South China Sea).

inner-lateral aspect of clasper. Ventral marginal cartilage with slender dorsal projection (present in all species of *Benthobatis* and other narcinids).

Dorsal fins with fleshy anterior portions and bases, slightly more similar in shape in males than in large female paratype (NTUM 01712); second dorsal slightly larger than first; anterior margins strongly sloping and broadly convex, especially on second dorsal in NTUM 01712; apices of dorsals narrowly rounded but more so in second dorsal (Fig. 7); posterior and inner margins not differentiated and weakly convex in first dorsal fin, but much more convex in second dorsal; dorsal bases smaller than anterior dorsal margins. Origin of first dorsal about opposite rear fourth of pelvic bases or about opposite their insertions. Interdorsal space about 0.8 times as long as base of first dorsal fin. Dorsal-caudal space about half of second dorsal base, and smaller than interdorsal distance. Caudal fin low and very elongated, its lower-posterior margin forming a continuous broad convex curve to tip of caudal; upper margin slightly less convex; caudal tip bluntly angular, with axis slightly raised; hypaxial lobe slightly shallower than epaxial lobe; its length about equal to distance from first dorsal origin to upper caudal origin.

Coloration.—Purplish or purplish-black on both dorsal and ventral surfaces in life, faded to medium or dark brown in preservative; dorsal, pelvic and caudal fins with lighter colored margins. Ventral surface with irregular lighter creamy blotches on disc, pelvic and caudal areas (Figs. 1B,4; see fig. 10 of Carvalho, 1999b for color depiction). Coloration in preservative somewhat variable due to fading, with irregular darker and lighter patches or streaks both dorsally and ventrally. Sensory pores frequently highlighted in darker pigment.

Derivation of Name.—In honor of Hung-Chia Yang (Taiwanese Fisheries Research Institute in Kao-Hsiung), for his research on Taiwanese cartilaginous fishes and superb illustrations of many of their species of fishes.

Discussion

Comparisons with Congeners.—*Benthobatis yangi* differs from all congeners by presenting (in preservative) a dark brown ventral coloration with irregular blotches of a light or creamy-white color (Figs. 1B,2B). Both *B. marcida* and *B. kreffti* have uniform white or off-white ventral surfaces, and *B. moresbyi* is uniformly dark brown ventrally

without any areas of lighter color (see color depictions of *B. moresbyi* in Carvalho, 1999b). *Benthobatis yangi* additionally differs from all three congeners in having a more narrow and straight (i.e., not posteriorly arched) suprascapula, and further differs from *B. marcida* and *B. moresbyi* by presenting higher numbers of caudal and total vertebral centra (Table 3).

Benthobatis yangi additionally differs from *B. moresbyi* in numerous proportions of the disc, tail and fins (Table 1), as well as in the shape of the dorsal fins. In *B. moresbyi*, the first dorsal fin is very broad (Carvalho, 1999b: fig. 4a) and relatively similar to the second dorsal fin in shape, while in *B. yangi* both dorsal fins have markedly different outlines (the second dorsal fin has a more slanted anterior margin, a much broader apex and more convex posterior margin compared to the first dorsal fin; Fig. 7; Carvalho, 1999b: fig. 4c). The disc is shorter in *B. yangi* (DL ranges from 38.6–41.5 % TL) compared to *B. moresbyi* (DL almost one-half TL in lectotype), as is the snout (PRN for *B. yangi* is between 10.6–11.7 % TL vs 16.4 % TL in *B. moresbyi*; POR ranges from 14.9–15.3 % TL in *B. yangi* vs 21.2 % TL in *B. moresbyi*; POB varies between 12.8–15.2 % TL in *B. yangi* vs 19.3 % TL in *B. moresbyi*). *Benthobatis moresbyi* also has a very short interdorsal space and second dorsal-caudal distance, a larger mouth and deeper circumoral grooves, broader gill slits, a shorter and depressed caudal peduncle, and a shorter precaudal tail compared to *B. yangi* (Table 1). Even though morphometric proportions may be somewhat distorted in the specimens of *B. yangi* (and *Benthobatis* generally) at our disposal, the differences at least in disc length, snout length, gill-slit width, and interspaces between dorsal fins and second dorsal and caudal fins, are considered reliable to separate both species because these distinctions are great and not too affected by postmortem desiccation (compared to less reliable proportions of the pelvic fins, for example).

Benthobatis marcida differs from *B. yangi* in being light brown dorsally (Bean and Weed, 1909), in having a thicker and fleshier disc, a broader interspiracular space (Table 1), in having thick, broadly rounded pelvic apices, and in the configuration of the caudal fin, which presents a more developed upper apex and is not nearly as low and narrow as the caudal fin of *B. yangi. Benthobatis yangi* is further distinguished from *B. kreffti* in having proportionally longer dorsal and caudal fins, and in presenting a low, ridge-like lateral tail fold (absent in *B. kreffti*). Both species, however, have higher numbers of caudal vertebrae than *B. marcida* and *B. moresbyi* (Table 3).

Size at sexual maturity is also somewhat different among species of *Benthobatis*. Male specimens of *B. yangi* sexually mature when between 191–215 mm TL (see below), which is distinct from both *B. marcida* (sexually mature males of 160 mm TL were examined) and *B. kreffti* (males mature at least by 162 mm TL; ISH 1989–1968). Sexual maturity is not precisely known for *B. moresbyi*, but occurs between 120–350 mm TL (Carvalho, 1999b). *Benthobatis moresbyi* and *B. marcida* are much larger species compared to the 'dwarf' species *B. kreffti*, and *B. yangi* is somewhat smaller than both former species as well (our largest examined specimen is the female paratype NTUM 01712). Chen and Chung (1971) reported their largest specimen to be 316 mm (presumably in TL), still smaller than examined specimens of both *B. moresbyi* and *B. marcida*.

BIOLOGICAL NOTES.—Stomach contents of the NHM paratype of *B. yangi* included mud and the partial remains of an unidentified polychaete worm, plus unattached polychaete bristles and unidentified small white objects. The spiral intestinal valve has only two turns in this specimen of *B. yangi*. Sexual maturity for males is reached between 191–215 mm TL, as observed in the SIO type-series. The smallest male paratype (161 mm TL) has

undeveloped claspers that do not project beyond the pelvic fins (Fig. 3D), while the largest specimen (holotype, Fig. 1B) has fully developed claspers with calcified terminal cartilage components. The 191 mm TL male paratype from SIO is intermediate between both of these specimens, with claspers projecting well beyond pelvic fin posterior margins (Fig. 3B), but without fully calcified terminal cartilages. The large female paratype (NTUM 01712) is assumed to be sexually mature due to its relatively large size.

Dissection of the smallest male paratype revealed that the eyeball is tightly connected to the surface integument, and that the 'eye-spot' barely visible externally is indeed a small pore. The eye is clearly innervated by the optic nerve, but presents extrinsic muscles that are highly atrophied, and this species (along with its congeners) probably does not have functional vision (histological studies are necessary to precisely determine this).

The smaller female paratype (NHM 1990.7.18.1) has interesting marks on the right pectoral disc that suggest an abortive bite by a shark. The dorsal surface shows an angular 'V' of tooth marks, while there is a narrowly arcuate set of tooth marks on the ventral surface. The bite shape matches quite well with *Hexanchus nakamurai* of approximately 480 mm TL (Ebert, 1990), rather than with the narrower-mouthed *Heptranchias perlo*, the broader-mouthed *Hexanchus griseus*, Taiwanese squaloids with broadly arcuate dental arcades, or other Western Pacific deep-water sharks. The slight penetration shown by the marks suggests that the *H. nakamurai* specimen gripped the ray but did not complete its bite, which could have been aborted due to an electric discharge from the specimen of *B. yangi*. We have also examined two specimens of the large torpedinid *Torpedo* "*nobiliana*" from the Cape coast of South Africa with light skin injuries suggestive of abortive attacks by hexanchid sharks, most likely *Hexanchus griseus*. One of these specimens has cuts on the dorsal surface of its disc that many have resulted when the attacking shark abruptly jerked its head away from the ray as it received an electric discharge while attempting to bite it (Ebert, 1994).

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Appendix

Measurements and their abbreviations used in this study are as follows (many of these are illustrated for sharks in Compagno, 1984): TL, total length (snout tip to posterior tip of caudal fin); PRC, precaudal length (snout tip to upper origin of caudal fin); DW, disc width (transverse width across apices of pectoral disc at greatest width); DL, disc length (snout tip to level of free rear tips of pectoral disc or, in those species without free rear tips, such as *Benthobatis* spp., to level of pectoral disc insertions); DT, disc thickness (greatest height of disc at midline over the scapulocoracoid); PRN, prenarial length (snout tip to level of anterior edges of nostrils, at incurrent apertures); POR, preoral length (snout tip to anterior edge of upper jaw or external tooth band); POB, preorbital length (snout tip to level of anterior margins of eyes); PSP, prespiracular length (snout tip to level of spiracle); PG1, prebranchial length (snout tip to level of first gill openings); HDL, head length (snout tip to level of fifth gill openings); PGW, preapical length (snout tip to level of greatest width of disc); PP2, prepelvic length (snout tip to level of pelvic origins); SCL, snout-cloaca length (snout tip to anterior end of cloaca); PD1, pre-first dorsal length (snout tip to first dorsal origin); PD2, pre-second dorsal length (snout tip to second dorsal origin); IDS, interdorsal space (first dorsal insertion to second dorsal origin); DCS, dorsal-caudal space (second dorsal insertion to upper caudal origin); PCA, pelvic-caudal space (pelvic fin insertion to ventral origin of caudal fin); PDO, pelvic-dorsal origin (pelvic origin to first dorsal origin); PDI, pelvic-dorsal insertion (pelvic insertion to first

dorsal insertion); NOW, nostril width (distance between outer edge of incurrent aperture and inner edge of excurrent aperture of nostril); INW, internarial width (transverse distance between inner edges of excurrent apertures); IOW, outer internarial width (distance across base of nasal curtain at incurrent apertures); SPL, spiracle length (longitudinal width of spiracle aperture); SPW, spiracle width (transverse width of spiracle aperture); INS, interspiracular width (distance between inner edges of spiracles on dorsal surface of head); MOW, mouth width (transverse distance between mouth corners); GS1, first gill slit width (distance between medial and lateral ends of first gill slit); GS2, second gill slit width (distance between medial and lateral ends of second gill slit); GS3, third gill slit width (distance between medial and lateral ends of third gill slit); GS4, fourth gill slit width (distance between medial and lateral ends of fourth gill slit); GS5, fifth gill slit width (distance between medial and lateral ends of fifth gill slit); IG1, inter-gill slit 1 (transverse distance between medial ends of first gill slits); IG5, inter-gill slit 5 (transverse distance between medial ends of fifth gill slits); CLL, cloaca length (longitudinal length of cloaca); PIW, pectoral insertion width (transverse width between pectoral disc insertions); TBH, tail base height (height of precaudal tail at pelvic insertions); TBW, tail base width (width of precaudal tail at pelvic insertions); CPH, caudal peduncle height (height of caudal peduncle at upper caudal origin); CPW, caudal peduncle width (width of caudal peduncle at upper caudal origin); P2L, pelvic length (distance from pelvic origin to free rear tip); P2A, pelvic anterior margin (distance from pelvic origin to fin apex); P2B, pelvic base (distance from pelvic origin to insertion); P2H, pelvic height (transverse distance from pelvic base to fin apex); P2P, pelvic posterior margin (distance from pelvic apex to free rear tip); P2S, pelvic span (transverse width across pelvic apices); CLO, clasper outer length (distance from pelvic insertion along outer edge of clasper to clasper tip); CLI, clasper inner length (distance from anterior end of cloaca along inner edge of clasper to clasper tip); CLB, clasper base width (transverse width across base of clasper); D1L, first dorsal length (distance from first dorsal origin to free rear tip); D1A, first dorsal anterior margin (distance from first dorsal origin to fin apex); D1B, first dorsal base (distance from first dorsal origin to insertion); D1H, first dorsal height (transverse distance from first dorsal base to level of apex); D1I, first dorsal inner margin (distance from first dorsal insertion to free rear tip); D1P, first dorsal posterior margin (distance from first dorsal apex to free rear tip); D2L, second dorsal length (distance from second dorsal origin to free rear tip); D2A, second dorsal anterior margin (distance from second dorsal origin to fin apex); D2B, second dorsal base (distance from second dorsal origin to insertion); D2H, second dorsal height (transverse distance from second dorsal base to level of apex); D2I, second dorsal inner margin (distance from second dorsal insertion to free rear tip); D2P, second dorsal posterior margin (distance from second dorsal apex to free rear tip); CDM, dorsal caudal margin (distance from upper caudal origin to rear tip of caudal fin); CPM, ventral caudal margin (distance from lower caudal origin to rear tip of caudal fin); CHI, caudal height (greatest transverse width of caudal fin); EOL, electric organ length (greatest longitudinal length of electric organ); EOW, electric organ width (greatest transverse width of electric organ at level of third gill slit or its mid-length).